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SURFACE PREPARATION AND COATINGS  
DESIGN/PRODUCTION INTEGRATION  
HUMAN RESOURCE INNOVATION  
MARINE INDUSTRY STANDARDS  
WELDING  
INDUSTRIAL ENGINEERING  
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U.S. DEPARTMENT OF THE NAVY  
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THE NAVY's CABLING AND WIRING COMPUTER PROGRAM  
(Known as C/W)

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## I. INTRODUCTION

In the mid 1960's the Computer Aided Ship Design and Construction project office, located in the Naval Ship Engineering Center, was chartered to apply computer aiding techniques to all phases of the naval shipbuilding process. A preliminary cost analysis in the electrical/electronic discipline pointed out the large amount of manual effort and time spent during installation design and production in the area of equipment cabling and wire hookup. After the aerospace industry's success in developing a productive wiring data system and an in-depth NAVSEC sponsored study at three designated naval shipyards of the cabling/wiring flow process during installation design, it was determined that a similar system should be developed for naval ship design and production. Because there are significant differences between 'wiring an aircraft and wiring a ship, a direct conversion from one application to the other was ruled out.

### Initial System Development

In 1965 the Westinghouse Electric Corporation was selected to develop a system of computer programs for processing the flow of electrical and electronic cabling/wiring information used in ship construction. This system was a major undertaking and addressed the entire process of installation design of equipment on board any Navy ship. This included such functions as cable routing, hanger selection, penetration design, planning and estimating supporting documents and the equivalent of all the necessary wiring plans. The objectives of the task were to:

• Aid the following production functions:

- Bulkhead penetration layout for thru ships cable
  - Installation of thru ships cable
  - Planning of local (within compartment) cable installation
  - Equipment installation
  - Equipment hookup
- Assist E/E design sections:
  - Compartment arrangements
  - Equipment selection through use of an automated equipment catalog
  - Checking production information

- Analytical design calculations (cable routing, voltage drop calculations)
- Aid Planning and Estimating Sections:
  - Start procurement of long lead time items
  - Prepare material and progress lists and job order forms

#### Test Implementation

The initial system was test implemented at two private shipyards, Avondale and General Dynamic/Electric Boat Division and at the Philadelphia Naval Shipyards. As a result of this trial implementation the system was shown to be too much, too soon. Aside from the normal problems associated with implementing a large computer software system, the test implementation showed that more work was needed in the planning and estimating area, and the data input required for cable routing was prohibitively large. The wiring section of the system performed very well.

#### Concentration On Local Layout and Installation

Following the initial development and test period by Westinghouse, Puget Sound Naval Shipyard was tasked to limit the system to those functions which indicated a ready acceptance and immediate payoff and to orient it to the Naval Shipyard environment.

The principal objective of the redirected Cabling/Wiring (C/W) system is the creation of a central configuration data management capability which will reduce drawing and installation time as well as revision and data transfer errors.

#### TI. INSTALLATION PROCESS

The process of installation design for electrical and electronic systems of new ship construction and major ship conversions are very similar given that the cableways have been established. The preparation of control documents begins just as soon as the information is available. In the case of conversion work the documentation available seldom reflects the "as wired ship", except for those specialized systems which have their own configuration management procedures. Also with conversions, there is a problem of ship checking before design. This problem can be alleviated through better life cycle change control. Assuming that all available information is correct, the process will provide the three production drawings that are required:

The equipment arrangement drawing is used to maintain interference control. A system designer requiring space must obtain a location from the arrangement designer. Controlled allotment of the finite volume available precludes physical interference at the time of shipboard installation. Architectural sketches are used to show the prospective locations of the various systems' equipment in the same compartment.

The Block or Isometric Cabling Diagram is required for both naval and

commercial vessels. It is a pictoral/tabular listing of how the equipment is to be interconnected in relation to the ship's hull. It contains a complete material record for a particular project or circuit. All material is purchased from information supplied on this drawing. E/E weights and moments are also usually recorded on the drawing and are used for weight control. The drawing does not show the physical relationship of E/E equipment on board ship. It is intended only to show cabling between systems and the cables' installation requirements.

The Elementary Wiring Diagram is primarily a registry for the disposition of each wire in every cable in a particular circuit.

The order in which the drawings are generated varies-according to the method of the system design. For instance, if it is designed from the end points back, such as power distribution or dial telephone, the sequence of the production drawings is different from the electronic system which is predefined. Predefined systems have most of the elementary wiring diagrams and room arrangement drawings provided at contract award time.

Specialized drawings such as foundation requirements and component assembly are supplied by the manufacturer and in some cases developed by the design codes from available information.

The primary objective of the drawings is to provide as much necessary information as possible using a minimum of detailed drafting. The drawings are composites of information required by several design and production users.

Therefore it is necessary for the individual user to cull out those portions that are of interest to him. For each such extraction, the probability of error is increased. Plainly there is needed a method to eliminate transcription errors and to ensure that work is being done to a consistent revision level.

The three drawings are referenced by the craftsmen to provide the information to perform the following tasks:

- Determine cableway routings and cableway penetration area clusters or riser boxes and install cableway support hardware at water tight decks and bulkheads.
- Pull cables that traverse compartments and decks, larger and longer cables first and establish breakouts (points where cables enter and exit a cableway).
- Pull within compartment (local) cables and cables which do not traverse cableways.
- Install connection boxes which link sections of cables. Cut cables.
- Begin installing equipment (all hardware, except main cables, is usually brought to an individual compartment as a package wherever possible).

- Fabricate plug ends on cables for all plug-connected equipment.
- Ring out wires in cables, prepare wire ends for hookup, apply branded sleeving wire markers (floaters) to wires.
- Close off transit devices, install cable markers, tie down cable groups in cableways.
- Complete all hooking up and labeling.
- Conduct installation testing: passive test for continuity of circuits, active tests of selected subsystems for correct equipment operation.

### III. PROBLEM AREAS

#### Design

The designer has the responsibility to develop the production type documents that reflect changes to the system. Getting the most current revision level of the drawings signed out and to the shops is a problem whenever the change must be cross referenced with many other production drawings. There is always the chance that composite type data can be extracted from drawings which are not at the current revision levels. This type of problem can be alleviated by having some method of producing all the necessary drawings at the same time from one source of information.

The designer puts out the job order description for the craftsman and the list of drawings needed for the task. The designer's time can be reduced by giving him the ability to ask for different documents which can describe:

(1) the circuits listed in the job order description, (2) the parts of a circuit or system, (3) the entire circuit or system.

The job order description lists those drawings that have been determined by the designer to be necessary or of value to the appropriate waterfront crew. Because work methods between installation crews vary, those designers not familiar with the different work crew methods may not list all drawings that may be useful to the crew in question. This becomes a significant factor when the shop must manually prepare an Equipment Terminal Layup for a large installation such as a fire control switchboard.

#### Craftsmen

The craftsmen must reference multiple drawings to develop a working sheet for the installation. A good example is the development of an Equipment Terminal Layup List. The craftsmen must reference sheets of wiring tables that are not always ordered such that they correspond to the sequential task of hooking up each terminator.

In some yards a card is prepared with all the composite type data for each cable of each IC, ECM, Radar, Electronics or Weapon System. These data are then sorted by equipment and printed out as a separate list. This is to get hookup data for one piece of equipment, and even then the data is not necessarily in proper hook-up sequence. What is needed is a scheme for the engineer to selectively produce a document having not only selected system information but also the correct order of hookup information. Thus the craftsman may install the wire connections in a sequential rather than haphazard order.

#### IV. C/W AND THE INSTALLATION FLOW PROCESS

The Cabling/Wiring System (C/W) aids the installation process providing the electrical and electronic information on listings which can be arranged into issuable work packages for installation.

The system is not (as yet) an analytical design system. The design is done by the engineers and designers. Only the organization and manner of the presentation of the information is changed from the customary elementary wiring diagram and isometric drawings to computer input and output listings, with the added advantage that the data elements of the input information be recorded just once.

The C/W System utilizes a master drawings file containing connection data. This data can be retrieved quickly and manipulated to produce many formatted output documents with minimum effort to prepare drawings for the different functions of production.

##### Input Data Requirements

The designer responsible for each system must identify the material to be presented on the drawings (listings) produced by C/W by using keypunch forms designed for use with the program. For each electrical/electronic system the designer must enter the minimum information required to obtain necessary installation work package drawings. This information may vary from ship to ship or from system to system, but for the most part, consists of four kinds of information:-

- (1) General drawing information such as the systems weight group, general notes, references, and NAVSEA drawing number.
- (2) Equipment information such as the description, location, and weight of equipment.
- (3) Cabling and wiring information such as the identity of the equipment connected on each end and the conductor termination points within each piece of equipment.
- (4) Procurement information such as the specification and grade or manufacturer's name and part number for each different type of material.

This information provides the groundwork from which all documents are prepared. The designer must identify and describe the individual items or components used in his system. Through the use of C/W, the designer is provided with a capability to consider only part of his system at a time. Cards used to describe an E/E circuit or system are collectively referred to as system definition cards and are the vehicle by which the designers get the information into the program. Output from the system is requested for a specific document by circuit or system.

#### Hierarchial Arrangement

Before a job can be submitted for processing by C/W, the input cards must be arranged in a sequence of hierarchial levels. This allows the user to describe an item at one level in terms of the items at successive lower levels. For example, an electrical/electronic system is described in terms of its equipment and cable data. In turn, each cable is broken down in terms of its note and conductor data.

A data file is built for each ship and consists of catalogs containing fixed data, e.g. equipment attributes, and circuit data about each electrical/electronic system to be installed or modified.

#### Automatic Lookup

Automatic catalog lookup is utilized for preparation of requested output documents called drawings to obtain additional information on those equipments and cables entered by the designer for each system stored on the file: This frees the designer from the time consuming task of manual lookup.

#### Document Variety

Information either entered by the designer or obtained from the catalogs, is used to produce a wide variety of documents. These documents are tailored to furnish the recipient with the information necessary to do the task.

The C/W master drawing file consists of most of the information contained on the three basic drawings traditionally used to prepare work packages.

The system currently produces the following documents:

(1) Wiring Table. A tabular listing of the detailed wiring connections necessary to hook up each cable in the electrical/electronic shipboard systems. Fig (1).

(2) Cable Installation Guide. Assists in the preparation of ships' compartment electrical layout.

(3) Equipment Cabling List. Shows the interconnecting local cabling between equipments in each compartment. Fig. (2).

- W I R I N G   T A B L E S

- U N I T A -  
MK 140 AMPLIFIER

NO. 3504

- U N I T B -  
ATTACK CENTER SWBD  
MK 41 MOD 3

NO. 3334

- C A B L E -  
N O .  
SYS. 6R-6PA-GAP  
REF 10. 10DO4  
TYPE. MSCA-19

G-GAP4

UNIT A TERM	WIRE MARKING	WIRE COLOR	GROUP	UNIT B TERM	WIRE FUNCTION	REF
2-3-05	17GAP28	BK		1 2FE-13	+26VDC COMMON	101
2-3-09	17GAAP210I	WH		2 2FN-04	GYRO ANGLE MARK 360 DPR TU 2	102
2-3-01	17GAAP102	R D		3 2FN-05	HVM MARK HIGH TUBE 2	103
2-3-08	17GAAP2103	GR		4 2FN-06	HVM MARK LOW TUBE 2	104
2-3-04	17GGAP821	OR		5 2FB-10	GYRO ANGLE LIMIT TUBE 2	105
<hr/>						
2-3-03	17GAAP822	8L		6 2FB-11	RUNNING DEPTH LIMIT TUBE 2	106
2-3-02	17GAAP823	WH-BK		7 2FB-12	ENABLING RUN LIMIT TUBE 2	107
4-3-05	17GAP40	R D - 8 K		8 2 F E - 1 4	+26VDC COMMON	108
4-3-09	17GAAP4101	GR-8K		9 2FN-10	GYRO ANGLE MARK 360 DPR TU 4	109
4-3-01	17GAAP4102	OR-BK		10 2FN-11	HVM MARK HIGH TUBE 4	110
<hr/>						
4-3-08	17GAAP4103	8L-8K		11 . 2 F N - 1 2	HVM MARK LOW TUBE 4	111
4-3-04	17GAAP841	8K-WH		12 2FE-10	GYRO ANGLE LIMIT TUBE 4	112
4-3-03	17GAAP842	RD-WH		13 2FE-11	RUNNINH DEPTH LIMIT TUBE 4	113
4-3-02	17GAAP843	GR-WH		14 2FE-12	ENABLING RUN LIMIT TUBE 4	114
*	NONE	BL-WH		15 *	SPARE	115
<hr/>						
*	NONE	BK-RD		16 *	SPARE	116
*	NONE	WH-RD		17 *	SPARE	117
*	NONE	OR-RD		18 *	SPARE	116
*	NONE	BL-RD		19 *	SPARE	119
<hr/>						
* TIE BACK AND INSULATE						
NOTE I-THIS SHEET REFLECTS ORDALT 7188.						
120						
121						

Figure 1.

CABLE. 6-GAP4

NAVSHIPS DRAWING NO. REV -SHEET-

FROM EQUIPMENT	TERM POINT	PLUG SYHB	CABLE NUMBER	CABLE TYPE	SIGNAL STATUS	CABLE STATUS	LENGTH (FEET)	TO EQUIPMENT
--- CABLES TO EQUIP IN --- COMPT .								
No. 3001			R-EZ13.	MSCA-19				
			P-EZ9	TSGA-23				
			R-EZ7	TSGA-14			PDB-1	
NO. 3002			R-EZ52	FSGA-9			PDB-6	
--- CABLES TO EQUIP IN -- COMPT. 03-99-0-C								
No. 3003			R-EZ130	MSCA-24			CONSOLE RADAR SET	
			R-EZ131	MSCA-14			OJ-227	
			R-EZ132	FSGA-3				
			R-EZ133	FSGA-9				
			R-EZ134	FSGA-9				
			R-EZ135	FSGA-23				
			R-EZ136	FSGA-23				
			R-EZ137	FSGA-23				
			R-EZ138	TTRSA-12				
----- LOCAL CABLES -----								
293			R-EZ110	3SWA-3				
			R-EZ124	SPECIAL				
			R-EZ125	SPECIAL				
			R-EZ62	SSGA-100				
			R-EZ53	FSGP-4			PDB-6	
			R-EZ58	TSGA-3				
			R-EZ164	TTRSA-12			INTERCONNECTION BOX	
							KCMX1	
--- CABLES TO EQUIP IN --- COMPT. 1-130-2-C								
No. 3004			R-EZ155	RG12A/U			VIDEO AMPLIFIER	
			R-EZ158	RG12A/U			AM-1914	
			R-EZ168	MSCA-10			SYNCHRO AMPLIFIER	
			R-EZ173	DSGA-3			MK2 MOO 2A	

Figure 2.

(4) Equipment Terminal Layup List. Assists the electrician in hook-up of connection boxes, switchboards, and other large on-board equipment.

(5) Equipment Cable Floater List. Provides marked sleeving information for individual wire markers.

(6) Connection Box Termination List. Assists the engineer or electrician in laying Up connection boxes frequently installed in electrical/electronic systems, such as interior communications, fire control and dial telephone systems.

(7) Circuit Check List. Aids the engineer and electrician in tracing any circuit installed in a given system.

(8) Equipment Terminal Locator Guide. Assists in tracing the point-to-point path through connection boxes-and switchboards of each circuit installed with the equipment.

(9) Ship Equipment List. An inventory of all the equipment either installed or to be installed.

(10) Cable Catalog List. A listing organized by cable type and size of the standard Navy cables used on board the ship.

Additional documents can easily be formatted and retrieved from the data base as need for them arises.

#### Revision Capability

C/W System is capable of almost infinite revision in its output. A keypunch operator can easily make up the revision cards from a copy of the output sheets marked up by the engineer to show the desired changes. The system will accept commands that will cause it to erase, add, correct, relocate, and/or re-designate. This is done simply by requesting a change for only the data elements effected. The entire system description need not be corrected. Just as a designer would not prepare a new drawing to change a wire number, he is not required by C/W to re-run the entire deck in order to achieve the equivalent of a drawing revision. The update operates with only the new data and a request to make the substitution. This feature provides for easy creation and rapid revision.

#### Missing or Invalid Information

C/W is designed to execute to completion on every computer run, regardless of errors which may have been punched in the cards. Missing or invalid information of practically any kind will not hinder normal processing. Diagnostic messages are printed to point out bad information in the submitted data, but do not stop execution. C/W continues to execute all processable data, leaving blanks whenever it encounters insufficient information. For example, a check is made to insure that the input length of a cable is actually a numerical value. If not, the program will in turn: inform the designer, blank the length, and

continue processing. Furthermore, if a revision is desired, two additional checks will be made. First, the drawing revision letter is checked to insure that it is actually alphabetic characters excluding the characters I,O,Q, and S, and second, the revision letter must be in proper order, that is, greater than or equal to the previous revision. If either check fails, the designer will be informed and the revision will not be made.

#### Fatal Errors

Certain errors, such as trying to modify the master file created for another ship, will cause the program to abort. These errors are termed "fatal errors".

#### Program Anticipation

If cards are discovered to be arranged improperly, the program will default to values that will allow partial output to be provided. These default values can then be easily identified and corrected. The arrangement or correctness of the input card deck is validated by the program. For example, if the designer fails to identify either or both equipments connected to one of the cables, an error message will be printed and the program will continue to process. Wiring tables will be printed for this cable, without the description and location of the unidentified equipment.

The intent is to process to completion partial circuit data and then complete processing in a later computer run.

#### Benefits

#### Where Was It Used

The following is a chronological list of ships for which the cabling/wiring system was used on various circuits at Puget Sound Naval Shipyard from 1970 to the present:

SSN	590	SSBN	608
CGN	25	SSBN	644
CV	63 (2 Overhauls)	SSBN	654
CV	64 (2 Overhauls)	SSBN	657
AOE	1	SSN	652
AOE	2	CGN	35
CGN	9	AS	32
CV	61	DDG	15
SSBN	623	DDG	16

It also has been used at Philadelphia Naval Shipyard on LCC 19 and at Charleston Naval Shipyard on CG 19.

The C/W System is now being implemented at Norfolk and Long Beach and is scheduled for implementation-in the other naval shipyards.

#### C/W System Implementation Support

Philadelphia Naval Shipyard has been tasked, as the Navy's C/W Tech Agent, to provide limited support to all shipyards during implementation. General Dynamics/Electric Boat has now implemented the system and, as a test, has produced Trident wiring tables.

#### Audited Savings

There exists no benefits data derived from the utilization of the present system because there has been no recent audit of the system. However, meaningful benefits data was derived for the predecessor of the C/W System. This is the information being presented here in Table 1. It must be understood" that the predecessor "Wires" was not as refined nor as user oriented as C/W and, therefore, gives a very conservative approximation of what can be expected.

The sum of \$971,938.000 of ship alteration funds was involved on four separate projects with dollar cost saving accrued of \$80,492.00. This indicates an average of 8.28% savings for each project processed by the system. The cost and savings data are based on actual audited costs for the WIRES system and the manual system it supplanted.

#### Future Use

The master drawing file is maintained during the construction or conversion/overhaul period for each ship processed. Measures are being taken whereby this file will become part of the ship drawing index and retained at the planning yard.

This file along with the plans can be used as a foundation to build new files for other ships of the same class. This is where full implementation of C/W system enters into the picture. The ultimate goal is to develop a file during the construction period and make it available in the future to the shipyard during conversion or overhaul.

#### Conclusions

This system is the first of what the author hopes will be a large number of computer aided ship design and construction programs to be developed and implemented by the Naval Sea Systems Command. It is expected that by applying these systems deliberately and diligently in an integrated shipyard modernization program, the total benefits of electronic data processing can be obtained, thus producing a better ship faster and at a lower cost.

SYSTEM	PRODUCT	COULD COST	DID COST	SAVINGS	ALLOWED
AN/SPN-42 RADAR	DEVELOPED CBOX DEFINED JUN BOX DELETED CABLES WIRE LISTS	\$ 3,300.00 6,994.00 26,928.00	-- \$1,863.00 0.00 6,038.00	\$ 1,467.00 6,994.00 20,890.00	\$182,000.00
DIAL TELEPHONE	WIRE LIST WIRE LIST TERM. LAYUP LIST		TOTAL ESTIMATED SAVINGS	\$29,351.00	( 6.12% OF ALLOWED)
		3,388.00 3,836.00	4,030.00 0.00	.642.00 3,836.00	\$276,516.00
			TOTAL ESTIMATED SAVINGS	\$ 3,194.00	1.25% OF A (WFN)
<b>USS CONSTELLATION</b>					
AN/SPN-42 RADAR	BOX JUMPERS SHIELD RE-ORDER PLUG RE-ORDER ISSUED DRAWINGS SHOP LABOR	3,067.00 99.00 4,136.00 26,929.00 ---	0.00 34.50 1,654.00 3,441.00 ---	3,067.00 64.00 2,481.00 23,487.00 3,663.00	\$237,600.00
DIAL TELEPHONE	WIRE LIST TERM LAYUP LIST CIRCUIT CHECK LIST SHOP LABOR		TOTAL ESTIMATED SAVINGS	\$32,767.00	(13.79% OF ALLOWED)
		3,836.00 3,836.00 3,836.00 ---	3,386.00 0.00 0.00 ---	450.00 3,836.00 3,836.00 7,051.00	\$275,822.00
			TOTAL ESTIMATED SAVINGS	\$15,185.00	15.60% OF ALLOWED
TOTAL SAVED \$80,492.00		TOTAL AMOUNT INVOLVED \$971,938.00		AVERAGE SAVINGS 8.28%	

Table 1. SAVINGS RESULTING FROM THE USE OF WIRES

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